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# **Carbohydrate Partitioning, Cultural Practices, and Vine Decline**

## **Diseases of Cucurbits**

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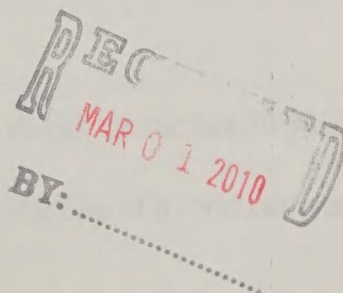
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## Pest Management

# Carbohydrate Partitioning, Cultural Practices, and Vine Decline Diseases of Cucurbits

*Additional index words.* root rot, crown rot, biomass partitioning, water use

**Abstract.** Cucurbit vine declines have become more widespread and are yield limiting in many production areas of the world. Coincident with the increased number and severity of these diseases has been many changes in cultural practices that include inadequate rotation, transplanting, plastic mulch, trickle irrigation, increased plant density, and the use of improved hybrid cultivars. The prevailing theory is that the vine decline diseases are more severe in hybrid cultivars, as opposed to open-pollinated cultivars, because of a heavier fruit-load that places the plants under added water stress as the fruit near maturity. We propose an alternative hypothesis. Specifically, we believe that the severity of crown rot and root rot vine declines is, in large part, due to carbohydrate re-allocation from the root to the fruit following fruit-set. Further, we believe that some current cultural practices play a role in predisposing plants to disease development.

Cucurbits are important crops in many parts of the world. In the last 20 years, there have been several changes in cultural practices including the introduction of hybrid cultivars, transplanting,





plastic mulch, drip irrigation, and increased plant density in the absence of adequate rotation. Some of these cultural changes have likely contributed to an increase in number and severity of soil-borne diseases which are responsible for significant economic losses, especially in muskmelon and watermelon. Among these are a group of diseases known as "vine declines" which are referred to as crown rot, root rot, sudden death, sudden wilt, wilt, and vine collapse. Cucurbit crops that develop vine decline generally appear healthy until 10 to 20 days before harvest. Symptoms are varied and often include a slight but detectable yellowing of the crown leaves. The yellowing may intensify with the death of crown leaves that gradually spreads throughout the vine. Consequently, fruit from affected plants are subject to sunburn, ripen prematurely, and may have reduced sugar content. In some cases, the vine decline is more rapid with the vine wilting and collapsing in a period of 1 to 3 days. Affected plants can exhibit one or more additional symptoms including xylem discoloration (vascular wilts), crown rot, root rot, or phloem discoloration. Although the symptoms may be strikingly similar and difficult to diagnose, these diseases are caused by an array of pathogens, primarily soil-borne fungi. The processes involved in the development of the vine decline diseases, with the exception of the *Fusarium* wilt, are not well understood. The diseases are manifested in a variety of ways and no doubt by several different pathways. The vine declines are rarely caused by a single pathogenic organism. Rather, they are most often caused by a disease complex, although, one pathogen may predominate. Fungi referred to as root pruners also contribute to the incidence of vine decline. The reader is directed to the Compendium of Cucurbit Diseases for more detailed information on the specific vine decline diseases (Zitter et al., 1996).

The vine declines classified as vascular wilts are caused by forma specialis of *Fusarium*



*oxysporum* Schlechtend.:Fr. emend. W. C. Snyder & H. N. Hansen (Martyn, 1996) and *Verticillium dahliae* Kleb. (Gubler, 1996). Restriction of water flow is generally considered to be the primary cause of wilt by *F. oxysporum* and *V. dahliae*. Consequently, carbohydrate partitioning may not play a significant role in development of these diseases.

The largest group of vine decline declines are caused by crown rot fungi which include *Didymella bryoniae* (Auersw.) Rehm (Chiu and Walker, 1949), *Fusarium solani* f. sp. *cucurbitae* W. C. Snyder & H. N. Hans. (Toussan and Snyder, 1961), *Lasiodiplodia theobromae* (Pat.) Griffen & Maubl. (Bruton, 1996b), *Macrophomina phaseolina* (Tassi) Goidanich (Bruton et al., 1987), *Myrothecium roridum* Tode:Fr. (Bruton, 1996a), *Phomopsis cucurbitae* McKeen (Bruton, 1996c), and *Phomopsis sclerotioides* van Kesteren (Ebben and Last, 1973). It is difficult to make generalized statements when discussing such a diverse group of fungi. However, the crown rot fungi typically infect the roots of seedlings soon after planting resulting in a high percentage of plants being infected prior to fruit-set. Lesions generally do not develop until about 10 to 15 days prior to harvest. As a rule, root rot is not associated with vine declines caused by crown rot fungi until the late stages of disease development. At that time, the roots may deteriorate quickly and create some confusion in diagnosis.

The root rot fungi which incite vine declines include *Acremonium cucurbitacearum* (Garcia-Jimenez et al., 1994), *Monosporascus cannonballus* Pollack & Uecker (Martyn and Miller, 1996), *Nodulisporium melonis* T. Watanabe & M. Sato (Watanabe and Sato, 1995), *Pythium* spp. (Gubler and Davis, 1996). As with crown rot, a high percentage of seedling may become infected by the root rot fungi prior to fruit-set. Early symptoms of root rot may not be evident, depending on the fungus involved. Vine decline normally does not occur until 15 to 20 days prior to harvest. The





1 root rot fungi do not cause crown lesions.

2 A phloem-limited bacterium has recently been associated with a vine decline of cucurbits in  
3 Texas and Oklahoma (Bruton et al., 1998) called yellow vine. Vines appear vigorous and healthy  
4 until about 10 to 20 days prior to harvest when the leaves begin to turn yellow. Within 3 to 4  
5 days, the vines may exhibit a blighted appearance that can easily be confused with other vine  
6 declines. A prominent and diagnostic symptom characteristic for yellow vine affected plants is  
7 the honey-brown discoloration of the phloem. In addition, root rot or crown lesions are not  
8 observed in plants exhibiting yellow vine.

9 There has been a tendency to attribute an increased fruit-load of recently developed hybrids as  
10 a major factor affecting the occurrence and severity of vine declines. Pivonia et al. (1997)  
11 demonstrated that muskmelon plants with an average of 2.5 fruit/plant exhibited 98% sudden wilt  
12 as compared to 12% in plants when fruit were removed at anthesis. They concluded that  
13 redistribution of photoassimilates due to fruit development may play a role in sudden wilt caused  
14 by *Monosporascus* sp. This is the first time this concept was introduced into the cucurbit vine  
15 decline literature. Others have noted that removing fruit reduced vine decline of muskmelon,  
16 caused by *M. cannonballus* (Miller, 1994; Wolff, 1996). Muskmelon plants with fruit removed at  
17 anthesis exhibited 62% vine decline caused by *A. cucurbitacearum* as compared to 93% vine  
18 decline in plants where the fruit were allowed to mature on the vine (Garcia-Jimenez, unpublished  
19 data). In contrast, removing fruit at fruit-set does not delay or reduce severity of vine decline of  
20 muskmelon caused by *M. phaseolina* (Bruton, unpublished data). Although fruit load “appears”  
21 to be directly correlated with vine decline, numerous factors are undoubtedly involved in the  
22 development of these diseases.





We propose that some vine declines may be intensified, in part, due to physiological root senescence and death as a consequence of the re-allocation of assimilates from the roots to the fruit following fruit-set. Since the causal organisms of this syndrome are a diverse group, it is likely that a combination of physiological and environmental factors are involved in the occurrence and severity of this group of diseases. In this paper, we review some of the current literature on carbohydrate partitioning and root development in cucurbits. We also discuss the possible relationships between carbohydrate partitioning, root physiology, and cultural practices that may exacerbate crown and root rot vine declines.

### **Carbohydrate Partitioning**

*Carbohydrate Source-Sink.* Many physiological and morphological changes occur from seed germination to fruit maturity. However, the physiological events which contribute to the development of vine decline have not been studied adequately. Carbohydrates are sources of energy for the cucurbit plant as well as the pathogen. If the plant is weakened at any stage of development, resistance to infection and/or disease development can be compromised. Carbohydrate synthesis, translocation, and catabolism are of central importance to growth and development of cucurbits (Haritatos et al., 1996). Schaffer et al. (1997) extensively reviewed carbohydrate metabolism in cucurbits and it is our intent to address this material as it may relate to mechanisms involved in vine decline of cucurbits. Until young leaves attain one-third to one-half their final size, when their photosynthesis is adequate to meet growth requirements and export the surplus, they obtain carbohydrates from older leaves (Wardlaw, 1968). The lower leaves act as the main source of assimilates for roots, the upper leaves provide assimilates for the



shoot apex, and leaves in the intermediate position may supply assimilates in either or both directions. This pattern of assimilate distribution is applicable to most plants. Stachyose and sucrose have been shown to be the major sugars in the translocate of the Cucurbitaceae (Hughes and Yamaguchi, 1983; Hendrix, 1968; Webb and Gorham, 1964; Webb and Burley, 1964; Mitchell and Madore, 1992; Webb, 1970). While stachyose is the predominant sugar in the cantaloupe leaf, monosaccharides comprise the largest amount of sugars in the young fruit and stem (Hughes and Yamaguchi, 1983). Richardson et al. (1982) noted that the highest levels of monosaccharides in the phloem exudate of *Cucurbita maxima* was adjacent to active sink regions. Monosaccharides made up 60% of the total sugars in *C. maxima* photoassimilate while stachyose comprised 46% of the total sugars in the stem internode Richardson et al. (1982).

The change from vegetative growth to flower and fruit production drastically alters the pattern of assimilate distribution. This is partly due to shifts in hormonal regulation which plays a major role in plant growth, fruit-set, and fruit development (Nerson and Paris, 1987; Rudich, 1990). The number of female flowers produced on muskmelon can exceed 50/plant (Jones and Rosa, 1928; Whitaker, 1931; Mann and Robinson, 1950). However, the number of fruit that reach maturity is normally low, ranging from 1 to 3 (Frazier, 1939). Birdsnest-type muskmelon exhibit a more concentrated fruit-set and can produce nearly 5 mature fruit/plant (McCollum et al., 1987). Watermelon and 'Hubbard' squash resemble muskmelon in their fruit-set habit (Mann and Robinson, 1950). It has long been established that fruit development in cucumber suppresses vegetative growth of the plant (McCollum, 1934; Pharr et al., 1985). The rate of leaf photosynthate increases significantly when the plant changes from vegetative to reproductive (Barrett and Amling, 1978; Pharr et al., 1985; Mayoral et al., 1985; Marcelis, 1991). When the





allocation of carbohydrates in the host is altered, the rate of disease development may also be altered.

Hartman and Gaylord (1942) noted that soluble solids were affected by leaf area/g of fruit. Hughes et al. (1983) demonstrated that carbohydrate movement to muskmelon fruit is primarily from leaves less than three nodes distal to the fruit. However, Kurata and Mizuno (1982) reported that the total leaf area was important for squash (*C. maxima*) fruit growth and that the position of the leaf was of no consequence. Older leaves of muskmelon plants have low net assimilation rates, and fruit growth depends on leaf number and their potential for carrying on photosynthesis (Acock et al., 1990). One week after anthesis, glucose and fructose levels increase about 10-fold in cantaloupe fruit (Hughes and Yamaguchi, 1983). Numerous studies have demonstrated high glucose and fructose in 10 to 20 day muskmelon fruit with dramatic increases in sucrose concentration about 10 days prior to harvest (Lu and Wang, 1959; Mizuno et al., 1971; Bianco and Pratt; 1977; Lester and Dunlap, 1985; McCollum et al., 1988). Sucrose can increase from 0.02 mg/g fresh wt in 15 day-old fruit to 39.0 and 64.0 mg/g fresh wt in 36 and 42 day-old cantaloupe fruit, respectfully (Hughes and Yamaguchi, 1983). A similar pattern of carbohydrate accumulation is found in watermelon (Elmstrom and Davis, 1981). During the sucrose accumulation phase, cantaloupe fruit with 1.0 kg of mesocarp may have a rate of dry weight (sucrose) increase of approximately 150 mg h<sup>-1</sup> (Schaffer et al., 1997). Muskmelon and watermelon, which lack a stored carbohydrate reserve, must remain attached to the plant for the accumulation of soluble sugars to occur (Tucker and Grierson, 1987; Hubbard et al., 1990b). Upon entry into cantaloupe fruit, the raffinose saccharides are rapidly metabolized and provide substrate for sucrose phosphate synthase (SPS), a key enzyme in sucrose biosynthesis (Hubbard et



al., 1989; Schaffer et al., 1997). In reports that evaluated sucrose metabolizing enzymes in muskmelon fruit, sucrose concentration did not increase unless SPS activity exceeded the sum of activities of the sucrose degrading enzymes (Hubbard et al., 1989, 1990a, 1990b; McCollum et al., 1988; Ranwala et al., 1991; Schaffer et al., 1997). The first fruit exerts the greatest sink on carbohydrates suppressing the growth of the remaining fruit (Marcelis, 1991; Stigter, 1969). Stephenson (1981) noted that most fruit abortion appears to be a response to limited resources, although, Schaffer et al. (1997) stated that limited photoassimilate is not likely the cause of fruit abortion.

*Root development and physiology.* The physiological and morphological modifications that occur following root infection are poorly understood. A knowledge of these interactions is fundamental to understanding the mechanisms involved in vine declines. These interactions are affected by environmental conditions which can be modified by cultural practices. Compounds released from root tissues stimulate complex microbial communities including pathogenic organisms (English and Mitchell, 1994). Root exudates consist of numerous compounds including carbohydrates, and are mediated by many factors including temperature, soil moisture, and plant development. Although there are numerous requirements for a parasitic relationship, carbohydrates probably play a major role. Root exudates are important in determining the success or failure of infection by some soil-borne pathogens (Schroth and Hildebrand, 1964). Glucose added to the soil stimulates the germination of *F. oxysporum* (Beckman, 1987). Root exudates may be required for germination of *M. cannonballus* ascospores (Stanghellini et al., 1996).

Epidemiological information on cucurbit vine declines is inadequate. In many cases, techniques to establish inoculum density in the soil are not available. Concepts involving soil



1 fungistasis, inoculum potential, inoculum efficiency, and inoculum density need to be  
2 characterized in relation to root disease (Benson, 1994). Huisman (1982) stated that the dynamics  
3 of root growth is an important component of disease progress curves for soil-borne pathogens.  
4 Disease assessment by root pathogens presents a difficult but challenging component of vine  
5 decline epidemiology. However, disease ratings possess an inherent fault in that they combine  
6 infection with disease development (Campbell and Neher, 1994). Therefore, assessment of  
7 infection vs. disease ratings need to be clearly stated.

8 Resistance to root infection, colonization, and development of vine decline have generally  
9 received little attention. There is evidence that demonstrates differential susceptibility to some  
10 crown and root rot vine declines within the Cucurbitaceae (Armengol et al., 1998; Bruton and  
11 Wann, 1996; Cohen et al., 1995; Mertely et al. 1993, Wolff and Miller, 1998). Some species  
12 within *Cucurbita* have shown potential as rootstock to control some vine declines (Garcia-  
13 Jimenez et al., 1990). Cucurbits produce a class of potent physiologically active compounds  
14 called cucurbitacins (Lavie and Glotter, 1971). Present evidence suggests that there are two  
15 families of cucurbitacins: B and E series based on the transformation of each into several different  
16 cucurbitacins (Rehm et al., 1957). Andrews et al. (1994) reported stimulation of *Pseudomonas*  
17 *fluorescens* and *P. lacrymans* using root extracts of *C. maxima* and *C. andreana* containing  
18 cucurbitacin B. This presents some interesting biocontrol possibilities. Infection of cucumber  
19 fruit by *Botrytis cinerea* has been reported to be inhibited by cucurbitacins (Bar-Nun and Mayer,  
20 1990). Some cucurbits may possess laccase-inhibiting compounds (Bar-Nun et al., 1988).  
21 Viterbo et al. (1993) reported that laccase activity was strongly repressed in *B. cinerea* by  
22 cucurbitacins B, E, D, and I. However, polygalacturonase, cellulase, and pectin methylesterase





production and activity were not affected. Several recent studies have shown that hypovirus infection of fungi suppresses expression the gene encoding laccase production. There is speculation and some evidence that hypovirus-mediated attenuation of fungal virulence may involve suppression of laccase (Choi et al., 1995). However, the role of cucurbitacins in the vine decline complex is still unknown.

Root growth and physiology in the cucurbits are the least studied and understood of all the plant organs. Yet, root health is the most important factor in plant growth and development as well as fruit production. The root system is likely the most vulnerable plant part since it is constantly in contact with potential root pathogens. Microbial infections of the root are numerous and constant during the growing season, although, many factors determine ultimate disease development. Structure and function of different types of roots vary with position within the architecture of the root system and may respond differently than the entire root system to stress, infection, and decay (English and Mitchell, 1994). Since vine declines are caused, for the most part, by soil-borne fungi, more effort should be made to study the physiological and ecological aspects of the cucurbit root system. Cucurbit root growth is generally extensive but shallow within the top 60 cm of soil. The illustrations by Bruner and Weaver, (1927) were the only detailed source found by the authors for cucurbit root growth and distribution. At fruit maturity, the taproot of watermelon and cantaloupe can reach more than 1 m in depth. Lateral roots of approximately 1 cm in diameter are extensively branched and fully penetrate the upper 30 cm of soil. Lateral roots typically extend beyond the area of above-ground runners. Lateral roots greatly diminish in number and length between 30 to 60 cm beneath the soil surface.

There is considerable economic incentive to plant or transplant as early as possible in many



cucurbit production areas, but this may also mean planting under suboptimal conditions. In temperate and sub-tropical areas, cucurbits are often seeded or transplanted into cool soils, which can result in plant stress. Low temperature was found to limit root respiration of cucumber and figleaf gourd via the cytochrome pathway (Tachibana, 1989). High temperature can affect root physiology as well. Du and Tachibana (1994a) noted that heat stress (38°C) initially promoted the translocation of photosynthates into the root of cucumber to meet the increased demand of carbohydrates for respiratory function. While stachyose decreased, significantly higher amount of raffinose accumulated in cucumber roots grown at 38°C possibly because the enzymatic processes of raffinose hydrolysis was impeded (Du and Tachibana, 1994a, 1994b). Excess soil water near the end of cucurbit production can reduce levels of fruit sugar. Root flooding can cause 30% reduction in root respiration and decrease in photoassimilate accumulation in the fruit (Kroen et al., 1991). They concluded that an increased demand for carbohydrates by the anaerobic roots may lead to a reduction in translocated carbohydrates available for sucrose biosynthesis in the developing fruit.

The distribution of translocated  $^{14}\text{C}$  in the roots of squash is similar to that in the hypocotyl and stem, and comprised primarily of stachyose, sucrose, hexose, and insoluble sugars (Webb and Gorham, 1964). When fruit are present, roots appear to be poor competitors for assimilates and receive only material in excess of the requirements of other plant parts (Vlugt, 1989). Marcelis (1994) noted greatly reduced cucumber root dry weight with increasing number of fruit/plant. Stigter (1969) reported that root growth in cucumber began to decrease within 3 to 4 days following fruit-set and stopped completely shortly thereafter, although roots did began to grow again following fruit harvest. Vlugt (1987) noted a similar pattern to root death (physiological





root death) in cucumber prior to harvest. Using glass panels, Post (1968) observed root growth of melon and cucumber plants with and without fruit. The number of healthy roots declined substantially in both species prior to fruit harvest. However, there was also a corresponding, but lesser, decrease in the number of healthy roots on plants without fruit. El-Keblawy and Lovett-Doust (1996a) reported 44% more root dry weight in muskmelon plants in which the fruit were removed 10 days following anthesis, as compared to plants allowed to produce mature fruit. Similar findings were reported in zucchini squash plants. Where the fruit were allowed to mature on the vine, plants had 36% less root mass as compared to plants where fruit were harvested using commercial standards (El-Keblawy and Lovett-Doust, 1996b). Vlugt (1989) noted that roots of *Cucurbita* spp. may possess a stronger sink for carbohydrates than many of the other cucurbits. This may help explain why some *Cucurbita* spp. are used for rootstock to control several soil-borne diseases.

## Discussion

Plant growth and vigor can be affected by many factors including fertility, soil conditions, genetics, and plant density. These factors can have a significant impact on vine declines. Historically, crown and root rot vine declines have been most severe in muskmelon. Since most of the research has concentrated on the diseases of muskmelon, our discussion will focus on this crop. Hybrid melon cultivars have practically replaced the open-pollinated cultivars in many cucurbit growing areas. The hybrids, with heavy fruit-load, have been associated with the increased incidence and severity of vine declines. However, when the open-pollinated cultivars are planted in fields with a history of vine decline, they typically succumb to vine decline disease



levels similar to the hybrids. In 1980, muskmelon production in the Lower Rio Grande Valley (LRGV) of Texas consisted of the open-pollinated cultivars TAM-Uvalde and Perlita which averaged about 1.5 marketable fruit/plant. *M. phaseolina* was the major cause of vine declines (Bruton et al., 1987). By 1984, muskmelon production had practically converted to hybrid cultivars. In 1986, *M. cannonballus* was the primary cause of vine decline of muskmelon in the LRGV (Mertely et al., 1991). Hybrid cultivars in 1998 averaged about 1.75 marketable fruit/plant in the LRGV. The primary difference in hybrid and the open-pollinated cultivars is uniformity of plant establishment, early harvest, more concentrated fruit-set for shortened harvesting period, and improved fruit quality and uniformity along with superior postharvest shelf-life of hybrid melons. World cucurbit production has changed dramatically in the last 20 years. Transplanting or direct seeding into plastic mulch with trickle irrigation, and increased plant density dominate current cultural practice. Some of these changes may contribute to increased plant stress and/or altered plant metabolism resulting in the increased incidence of vine declines. It is interesting to note that some of the vine declines appeared to become a problem in Israel (Reuveni et al., 1983), Spain (Garcia-Jimenez et al., 1994; Lobo-Ruano, 1990), and the United States (Bruton et al., 1995; Mertely et al., 1991) at approximately the same time. It is generally accepted that the pathogens are indigenous to the regions and not a matter of recent fungal movement or introduction. Because of the diversity of cultivars produced in the respective regions, increased susceptibility to vine decline organisms does not seem plausible to account for the severity of these diseases. In fact, there is insufficient tolerance within the commercial muskmelon cultivars for adequate control of the root rot vine declines. These occurrences suggest other, or additional, causes for the coincidental increase in incidence and severity of vine declines in cucurbits.



1 In temperate and sub-tropical areas, unfavorable conditions due to early planting can be  
2 mediated to some degree by the use of plastic mulch and trickle irrigation. Depending on  
3 environmental conditions, transplanting muskmelon and watermelon on black plastic can decrease  
4 the time to harvest by 10 to 20 days and often increase yields (Brown and Olson, 1989; Elmstrom,  
5 1973; Olson et al., 1994; Simonov, 1975). However, some vine declines are intensified in  
6 transplanted muskmelon and watermelon. Transplants have a greatly altered root architecture  
7 with no tap root (Elmstrom, 1973). Direct seeded muskmelon can produce near normal yield in  
8 the same field in which transplants are severely affected by *M. cannonballus* (Miller and Bruton,  
9 personal observation). Using plastic mulch and trickle irrigation, watermelon roots were found to  
10 occur in a cylindrical volume of soil centered around the trickle tubing, with an average of 71% of  
11 all roots occurring within 0.3 m of the tubing (Pier and Doerge, 1995). Similar results were  
12 reported for trickle-irrigated watermelon and cantaloupe (Bhella, 1985, 1988). Consequently, the  
13 roots are concentrated in a smaller area making them less efficient and perhaps more vulnerable to  
14 root diseases. However, the root rot vine decline caused by *M. cannonballus* is mediated  
15 somewhat by plastic mulch.

16 Excess water (rain or irrigation) near the end of the season can impair normal physiological  
17 functions of the roots and intensify vine collapse. Adequate but prudent irrigation, based on soil  
18 moisture readings, are essential for trickle irrigation. In many cucurbit production areas, salinity  
19 levels can impede normal plant growth. Although cucurbits are considered to be moderately salt  
20 tolerant, high salinity levels can decrease leaf area, plant growth (Franco et al., 1993; Mendlinger  
21 and Pasternak, 1992) and fruit yield (Mangal et al., 1988). Cantaloupe cultivars possessing larger  
22 root systems appear to have greater tolerance to the vine decline caused by *M. cannonballus*.





Walters and Wehner (1994) derived a system to evaluate root size in cucumber that was highly correlated with quantitative root traits such as dry weight. Genetic improvement of root characteristics has largely been ignored in the cucurbits, yet it may offer tremendous opportunity that could have a profound effect on decreasing the incidence and severity of some vine declines.

Plant density affects the micro-environment of shoots and root, which, in turn affect leaf area/plant, and crown and root mass. Numerous studies have shown that high plant density of muskmelon and watermelon can reduce the leaf area, total dry weight of plants, and marketable yield/plant (Brinen et al., 1979; Cantliffe and Phatak, 1975; Knavel, 1991; Widders and Price, 1989). Reducing plant density can increase concentrations of total soluble solids in muskmelon fruit (Davis and Meinert, 1965). Consequently, increased plant density can have a critical impact on plant biomass partitioning, photoassimilate availability, and possibly incidence and severity of vine decline. The effects of plant density on vine decline epidemiology has largely been ignored.

Under spring conditions in the LRGV of Texas, direct-seeded cantaloupe begin producing male flowers at about 24 days, female flowers and fruit-set begin at about 27 to 30 days, and harvest occurs about 40 days after fruit-set. Adjustments can be made for cucurbit species, transplants, and different environmental conditions. A "Conceptual Model" for cantaloupe relative biomass partitioning, at fruit-set, and at harvest are presented for the purpose of relating developmental stage to the onset of vine declines (Figure 1). The estimated percentages of biomass partitioning of cantaloupe were extrapolated from numerous sources and our data. Water-use data for spring melon production in the LRGV was provided by R. Weidenfeld, Texas A&M University (unpublished data).

Once fruit-set begins, photosynthetic rate increases (Marcelis, 1991). However, additional



fruit do not increase the photosynthetic rate proportionally. Photoassimilates become limiting soon after fruit-set as demonstrated by decreased rate of vegetative growth (Figure 1). Pivonia et al. (1997) noted that foliar dry weight accumulation ceased about 33 days after transplanting which would correspond to the early stage of fruit development. Root mass at the time of harvest can be as much as 40% less than similar plants with fruit removed at anthesis. The physiological changes that occur in the root and the resulting reduced growth rate may allow fungal pathogens to colonize a greater proportion of the root or crown tissue following fruit-set. Hegde (1988) reported an increase in leaf area of watermelon plants up to about 80 days with the maximum rate of increase between 21 and 40 days. This is consistent with cantaloupe and cucumber plant development since direct-seeded watermelon requires approximately 90 to 100 days to fruit maturity. Cucurbit fruit typically exhibit a sigmoidal growth curve (Davies and Kempton, 1976; Lorenz, 1949; Ranwala et al., 1991; Schapendonk and Challa, 1980; Sinnott, 1945; Hegde, 1988). This creates a heavy demand on available carbohydrates between 40 and 60 days after planting which is just prior to the period of time when vine declines normally develop (Figure 1). At the same time, root growth rate slows dramatically as carbohydrates become limiting.

Generally, it is not a matter of whether infections will occur, but whether the infections will ultimately result in the development of vine decline. A high percentage of the roots can become infected prior to fruit-set with the one or more of the vine decline pathogens. Environmental and cultural conditions along with many plant physiological factors can dictate the ultimate occurrence and severity of vine decline. Plant health and vigor also appear to play a role in the severity of vine declines. As previously stated, the implication has been that the hybrid cultivars are more susceptible to vine decline than open-pollinated varieties. Also, it has been proposed





that the higher fruit load of hybrid cultivars is responsible for the added stress on the plant caused by increased water demand of the additional fruit. Our research shows that open-pollinated and hybrid cultivars are essentially equally susceptible. We suggest that the increase in fruit load is not of itself responsible for the increase in vine decline. In fact, there is not much of an increase in fruit-load in the hybrid cultivars. Since they may have a more concentrated fruit-set, it is likely that they may have less tolerance for root loss caused by root rotting vine decline pathogens. In the last 15 days prior to harvest, the entire plant increases by perhaps less than 10% total biomass. Based on data of Ranwala et al. (1991), muskmelon fruit increased in weight by only 11% between 34 and 50 days when abscission occurred. Therefore, almost 90% of fruit growth occurred prior to the time we would expect to observe vine decline. If mature fruit weigh in the vicinity of 1.5 to 2.0 kg/fruit, the amount of water/fruit would be approximately 1.4 to 1.8 L. Cantaloupe cv. 'Magnum 45' direct-seeded on about 15 cm spacing can have approximately 300 leaves with a leaf area of 4 m<sup>2</sup> at first harvest averaging 3 melons/plant (total = 3.3 kg) (Russo and Bruton, unpublished data). Since the mature fruit averaged 1.5 kg, this leaves about 1.8 kg for the remaining 2 fruit. Water use rate, calculated on spring production, for melons in the Lower Rio Grande Valley was sigmoidal (R. Wiedenfeld, personal communication) ranging from approximately 1.0 to 1.3 liters/plant/day between 50 days after planting and harvest (Figure 1). If marketable cantaloupe fruit weigh approximately 1.5 to 2.0 kg of which about 93% is water, we calculate that it would take approximately 0.3 L of water for the added fruit weight during the last 15 days before harvest. This does not take into consideration the evapotranspiration of the fruit which is 15%. However, increased water demand to produce the fruit in the last 15 to 20 days of development cannot account for the increased severity of vine declines.



There are no simple explanations to account for the development of vine declines especially since they can be caused by such a diverse group of microorganisms. We propose that the increase in vine decline incidence and severity coinciding with the introduction of hybrid cultivars is circumstantial and that reverting to use of the open-pollinated cultivars would provide no cure. Although carbohydrate partitioning appears to play a role in many of the vine declines of cucurbits, verification requires intensive scientific investigation. Changing cultural practices have contributed to overcoming many obstacles in cucurbit production. However, some of these practices may also be contributing to the increased severity of cucurbit vine declines. This complex arena of unanswered questions provide numerous avenues of research including effects of plant density, carbohydrate partitioning, root characteristics, root physiology, and cultural activities as they relate to vine decline development.

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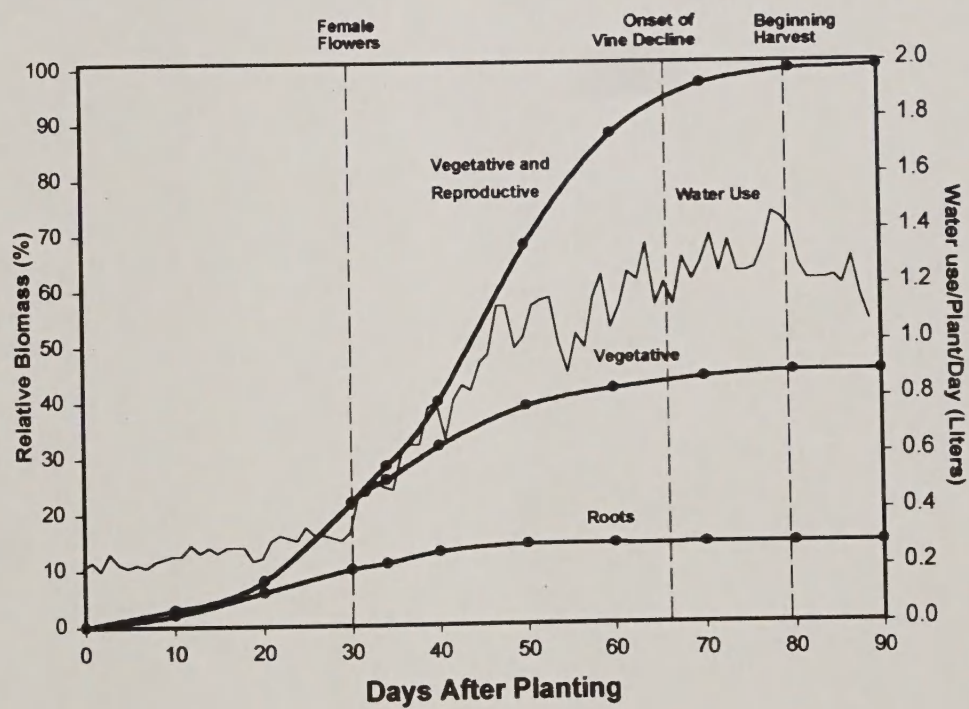
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Figure 1. Conceptual Model of cantaloupe biomass partitioning with respect to plant development, vine decline, and water use rate. Growth parameters were extrapolated from our data and data from several other sources (Caudal et al., 1985; El-Keblawy and Lovett-Doust, 1996; Hegde, 1988; Marcelis, 1994; Post, 1968; Ramirez et al., 1988; Schapendonk and Brouwer, 1984). Water use data were provided by R. Wiedenfeld, Texas A&M University (unpublished data).











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